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INFLATOR CAPABLE OF MODULATION AIR BAG INFLATION RATE IN A VEHICLE OCCUPANT RESTRAINT APPARATUS

This application claims benefit under 35 U.S.C. § 119(e) of U.S. provisional application No. 60/037,234, filed Feb. 3, 1997.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to vehicle occupant restraints and more particularly to a "smart" airbag apparatus capable of modulating inflation characteristics in response to collision and occupant parameters.

2. Description of the Related Art

Many vehicles on the road today include airbags installed in steering wheels, dashboards, and more recently, doors. These airbags are designed to protect a vehicle occupant against both front and side impact collisions by rapidly inflating the airbag to absorb much of the collision energy that would otherwise be transferred to the occupant.

Such conventional airbags are inflated based on a single threshold test: if a predetermined vehicle deceleration occurs in a collision, airbag inflation is triggered. Thereafter, airbag deployment occurs at a predetermined inflation rate. Both the triggering threshold and the inflation rate are not modified based on the type of vehicle collision, or the many different occupant variables, such as occupant weight, occupant position at the moment of impact, etc.

This inability to modulate inflation characteristics has resulted in serious injuries, even deaths, because of the existence of airbags in the vehicles had not been equipped with. This is because the explosive force of inflating airbags impacting occupants, particularly infants, the elderly, and those not wearing seat belts, can be more harmful than the accidents would otherwise have been.

Therefore, a need exists for a "smart" airbag apparatus which provides modulated airbag deployment based upon dynamics of the collision and occupant parameters.

SUMMARY OF THE INVENTION

An objective of the invention is to provide a vehicle occupant restraint apparatus capable of modulated airbag deployment.

Additional objectives and advantages of the invention will be set forth in part in the description which follows, and in part will be obvious from the following description, or may be learned by practice of the invention.

In accordance with the objectives and purpose of the present invention, as embodied and broadly described herein, the invention comprises an occupant restraint apparatus for installation in a vehicle. The apparatus includes an airbag and an inflator. The inflator includes a combustion chamber in fluid communication with the airbag, a reservoir containing a liquid propellant, a port fluidically interconnecting the combustion chamber and the liquid propellant reservoir, an inflation initiator operable, in response to an accident involving the vehicle, to pressurize the liquid propellant reservoir, such that the liquid propellant is injected through the port into the combustion chamber for ignition and generation of combustion gases to inflate the airbag. The apparatus further includes a sensor for generating a signal indicative of an accident parameter, and a controller for varying a combustion rate of the liquid propellant in the combustion chamber in accordance with the sensor signal, thereby modulating an inflation rate of the airbag.

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In accordance with another aspect, the present invention comprises an airbag inflator including a housing, a combustion chamber provided in the housing, a reservoir provided in the housing for containing a liquid propellant, a piston slidingly received in the housing and having a first piston head separating the combustion chamber from the liquid propellant reservoir, an injection port, and a pyrotechnic initiator. The pyrotechnic initiator is detonated in response to a vehicle accident to pressurize the combustion chamber and to ignite liquid propellant injected into the combustion chamber from the reservoir through the injection port during a regenerative pumping stroke of the piston, where combustion of the injected liquid propellant occurs to produce airbag inflation gasses. The airbag inflator further includes a controller operable to vary a rate of the piston's regenerative pumping stroke according to at least one accident parameter, thereby modulating a rate of airbag inflation during airbag deployment.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one embodiment of the invention and together with the description, serve to explain the principals of the invention. In the drawings:

FIG. 1 is a sectional view of a "smart" airbag inflator, partially in block diagram form, configured in accordance with a presently preferred embodiment of the present invention; and

FIG. 2 is a side view of an injection port tube member utilized in the embodiment of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the present invention, and as embodied herein, an airbag apparatus, generally indicated at **10**, comprises an inflator, generally indicated at **14**, for inflating an airbag **12** in response to a vehicle accident. Inflator **14** includes a cylindrical housing **16** closed off at its left end by a rear closure, generally indicated at **18**, and at its right end by a front endwall **20**. The rear closure **18** includes an annular wall **21** integrally formed with a forwardly extending tube **22**, and a rearwardly extending annular chamber **24**. The rear closure **18** and front endwall **20** are fixed in place by suitable means, such as welded joints, to prevent fluid leakage.

The cylindrical housing **16** is machined to provide a stepped bore for receiving a piston, generally indicated at **30**, which includes a radial piston head **32** and a rearwardly extending skirt **34** slidingly received in housing bore **28**. The piston skirt **34** is terminated in an annular piston head **36** that is slidingly received between housing bore **38** and an outer cylindrical wall **40** of rear closure **18**. This annular piston head **36** operates in an annular chamber **46** and is sealed against fluid leakage by suitable means, such as O-rings **42**, **44**.

Radial piston head **32** divides the interior portion of cylindrical housing **16** defined by bore **28** into a combustion chamber **48** and an annular reservoir **49** containing liquid propellant **50**. As disclosed in U.S. Pat. No. 5,060,973 to Giovanetti and U.S. Pat. No. 5,487,561 to Mandzy et al.,

which are herein incorporated by reference, the liquid propellant may be a hydroxyl ammonium nitrate-based liquid monopropellant. A particular suitable propellant composition comprises, by mass, approximately 60% hydroxyl ammonium nitrate (HAN) as an oxidizer, 20% triethyl ammonium nitrate (TEAN) as a fuel, and 20% water as a diluent.

A central injection port **51**, drilled axially through the piston head **32**, is normally closed by a terminal portion **54** of tube **22**, which serves as a needle valve element. Thus, terminal portion **54** is slidingly received in injection port **51** and is machined with an annular groove accommodating an O-ring **54***a*, to provide a fluid seal with the injection port sidewall. As seen in FIG. **2**, at least a pair of diametrically opposed, longitudinal grooves **52** are cut in the peripheral surface of tube **22**, beginning an appropriate distance rearwardly of injection port **51** and extending back to annular wall **21**. Also as seen in FIG. **2**, at least one additional longitudinal groove **56** is cut in the tube peripheral surface, beginning at O-ring **54***a* and extending rearwardly to annular wall **21**.

Seated in the shouldered central opening of annular wall **21** is a squib **62**, which is held in place by a snap ring retainer **66** and annular plug **68**. The interior of tube **22** forwardly of squib **62** stores a solid propellant booster charge **72**. This booster charge **72** may be boron potassium nitrate, which is ignited by electrically initiated detonation of the squib **62**. The byproducts of the booster charge combustion exit tube **22** through an opening **74** in terminal portion **54**, which is normally closed by a frangible seal **76**.

When squib **62** is fired to ignite the booster charger **72**, seal **76** is ruptured, and combustion gases flow into combustion chamber **48**, which is then pressurized. To permit initial rearward movement of piston **30** sufficient to open the forward end of groove **56** to the combustion chamber **48**, an appropriate volume of a compressible fluid, such as air, is included in liquid propellant reservoir **49**. The communication then created between liquid propellant reservoir **49** and the combustion chamber **48** through groove **56** allows liquid propellant **50** to flow into the combustion chamber **48** for combustion. Due to the differences in the surface areas of the piston head **32** facing the reservoir **49** and the piston head surface facing the combustion chamber **48** resulting from the presence of the cylindrical skirt **34**, the fluid pressure in the reservoir **49** always exceeds the fluid pressure in the combustion chamber **48**. Consequently, regenerative pumping of the liquid propellant from the reservoir **49** into the combustion chamber **48** is achieved. As piston **30** progresses through its rearward stroke, grooves **52** open into combustion chamber **48**, thereby increasing the opening area of injection port **51**, and the injection rate of liquid propellant into the combustion chamber **48** increases accordingly. Liquid propellant injection into the combustion chamber **48** by regenerative pumping and its combustion continues until piston head **32** bottoms out against annular wall **21**, at which point the entire volume of liquid propellant has been pumped from reservoir **49** into the combustion chamber **48** and combusted to complete airbag deployment.

Chamber **24** provided between outer cylindrical wall **40** and inner cylindrical wall **41** of closure **18** slidingly receives an annular piston **80**. The forward end of chamber **24** is vented to the atmosphere, as indicated at **81**. Inner cylinder wall **41** of closure **18** extends rearwardly to mount a collar **88**, which, in turn, mounts an annular electromagnet **86**. Field piece **90** of this electromagnet, together with collar **88**, inner cylindrical wall **41**, and piston **80**, define an annular chamber **84**, which communicates with annular chamber **46** through a plurality of orifices or a single annular orifice indicated at **92**.

In accordance with a feature of the present invention, chambers **46** and **84** are filled with a variable viscosity damper fluid, such as a magneto-rheological fluid **83**. Magneto-rheological fluids, such as carbonyl iron particles suspended in silicone oil, as disclosed in U.S. Pat. No. 5,284,330 to Carlson et al., have a unique property in that viscosity can be controlled by a magnetic field.

As can be seen in FIG. **1**, as piston **30** strokes rearwardly to pump liquid propellant **50** into combustion chamber **48** for combustion, piston head **36** is driven rearwardly through chamber **46**. Magneto-rheological fluid **83** is thus forced to flow through orifices **92** from chamber **46** into chamber **84**, and piston **80** is driven forwardly through chamber **24**, which serves as a containment reservoir for the fluid **83**. By controlling the viscosity of fluid **83** and thus its rate of flow through orifices **92** using a controllable magnetic field produced by electromagnet **86**, a variable retarding force can be exerted on the rearward stroke of piston **30**. Since the rate of rearward stroke of piston **30** governs the liquid propellant combustion rate, and, in turn, airbag inflation rate, the magnitude of the magnetic field produced by electromagnet **86** can be advantageously utilized to control airbag inflation rate on a real time basis. Thus, if no current is applied to electromagnet **86**, the viscosity of damper fluid **83** is at its lowest value and the airbag inflation is at a maximum rate. When current is applied to the electromagnet **86** to produce a high magnetic field, piston stroke can be dramatically retarded to produce a gentle airbag deployment. In fact, a magnetic field of maximum magnitude can actually stop the flow of damper fluid through orifices **92**, which will arrest the rearward stroke of piston **30** and thus stop further airbag inflation. Between no magnetic field and maximum magnetic field are an infinite number of airbag inflation profiles that can be produced by real time variations of the magnetic field during an inflation period.

Further in accordance with the present invention, the magnetic field produced by electromagnet **86** is varied in response to signals produced by a sensor suite **94**, including, for example, a crash severity sensor **96**, a rear-facing infant seat sensor **98**, an occupant weight sensor **100**, a dashboard proximity sensor **102**, and a seat belt sensor **104**, etc. A central processing unit **106** processes the sensor outputs according to an appropriate algorithm, such as to modulate the airbag inflation rate during deployment according to a particular scenario of collision and occupant parameters.

Completing the description of inflator **10**, a generally cup-shaped partition **108** is inserted into housing **16** in press-fit relation, with its open end closed by front endwall **20** and its closed end portion defining a forward boundary **110** for combustion chamber **48**. A convoluted sleeve **112** serves to retain the position of partition **108** in the manner described in commonly assigned, U.S. Pat. No. 5,829,784, the disclosure of which is incorporated herein by reference.

The interior of cup-shaped partition **108** provides a swirl chamber **122** in fluid communication with combustion chamber **48** through a plurality of equiangularly spaced swirl ports **124** in partition wall section **110**. The term "swirl" is intended to characterize ports **124** as being configured to achieve a circular or swirling flow of fluid (combustion gases) in chamber **122** upon entry from combustion chamber **48**. For this purpose, ports **124** may be drilled through partition wall section **110** at an oblique angle such that gases enter chamber **122** closely tangential to the inner cylindrical surface of the partition wall section **110**.